A TRACKING SYSTEM

FIELD OF THE INVENTION

The present invention relates to a tracking system comprised
5   in a receiver, and to a method for tracking rapid changes in
frequency and phase offset in a receiver. In addition, the
present invention relates to at least one computer program
product for tracking rapid changes in frequency and phase
offset in a receiver.

10

BACKGROUND OF THE INVENTION

A well-known issue in designing transceiver systems in which
rapid transitions must be made between e.g. receive and
transmit states or between idle and receive states, is that
15   the local oscillators on the system can suffer a perturbation
from their stable operating frequency. This can, for example,
be due to a sudden change in load on the power supply. An
example of such a glitch is shown in Figure 1, related to the
preamble of an IEEE 802.11 WLAN OFDM transmission. In Figure
20   1, reference numeral 2 denotes the short preamble symbols, 4
denotes the cyclic prefix (CP) and the long preamble symbols,
6 denotes the SIGNAL field and 8 denotes the data symbols.
The VCO frequency is shown initially at one stable level;
when the transmission begins, the operating conditions change
25   and the VCO moves to a different stable operating frequency.
Since the VCO operates in a feedback loop, it takes time for
the frequency to converge on the new stable operating
frequency.

30   Although it may be possible to design ones own receiver to
have an extremely stable VCO, it is impossible in an open
market such as that for WLAN devices to be sure that competi-
tors' devices have equally high standard for their transmit-

1

ters. To be interoperable, it is therefore necessary to be able to compensate for such deviations.

In a typical WLAN receiver, an initial coarse estimate of the frequency offset will be made during the short preamble sym-
5   bols. A more precise estimate will be made during the long preamble symbols. The changing frequency of the VCO means that the frequency estimates are likely to be inaccurate; and even if a fairly accurate frequency estimate has been made by the end of the long preamble symbols, the frequency is likely
10   to change further.

The problems caused by a residual frequency error will be explained with reference to the operation of a simplified digital OFDM receiver datapath as shown in Figure 2.

The first operation in the datapath is to correct the fre-
15   quency error, which is achieved by a progressively phase rotation of the incoming I / Q samples, which is intended to exactly cancel out the phase rotation of the incoming signal due to the frequency offset. In the absence of any other input, the frequency correction is based on the initial fre-
20   quency estimate.

This operation is performed in the frequency correction block 10.

25   The next operation is to perform a fast Fourier transform (FFT), at the block 12, on the received data. This separates the received time-domain symbol into a number of independently modulated sub-carriers. In an 802.11a OFDM transmission, there are 52 sub-carriers, of which 48 are used

to transmit data and 4 are pilot tones modulated with a known
sequence.

Next, the sub-carriers extracted by the FFT 12 are demodu-
lated, at the demodulation block 14, (converted from symbols
5   into [soft] data bits). In order to perform the demodulation,
it is necessary to have an estimate of the channel transfer
function for each subcarrier, which is represented by a scal-
ing and a rotation of the transmitted constellation. The ini-
tial channel estimate is typically obtained during the long
10 preamble symbols.

Finally, error correction, at the error correction block 16,
is applied to the received data stream. In an 802.11 OFDM
transmission, a Viterbi decoder is typically used to perform
the error correction function.

15

D denotes the data outputted from the OFDM receiver.

A residual frequency error means that the frequency
correction block will not completely remove the frequency
20 offset. The first problem that this causes is that there is a
progressively increasing phase rotation of the received
signal at the output of the frequency correction block. The
demodulation process is based on the received signal phase as
estimated during the long preamble. The progressive phase
25 rotation caused by the frequency error means that there will
be an increasing phase error with respect to the channel
estimate. At a certain point, this will lead to uncorrectable
demodulation errors. An example of this is shown in Figure 3:
the unrotated received I / Q vector is shown as a solid line,
30 and is near to the correct constellation point corresponding
to the transmitted data. E denotes the correct constellation

point for received vector and F denotes all of the ideal constellation points according to channel estimate. As the received vector is progressively rotated away from E, it is clear to see that at some point demodulation errors occur. To

5 keep a reasonable degree of clarity in the figure, the example shown uses 16-QAM modulation; IEEE 802.11 OFDM transmissions also use 64-QAM for higher rate transmissions. Since 64-QAM has 4 times as many constellation points it is clearly much more sensitive to phase errors.

10 A second problem, caused by moderate to severe frequency estimation errors, is loss of orthogonality in the FFT. In the absence of a frequency error, the subcarriers are perfectly separable from one another (the energy from one subcarrier does not interfere at all with another subcarrier). However,

15 if the frequency offset becomes at all large, a significant amount of inter-carrier interference occurs which is visible as noise in the signal at the demodulator.

If it is possible to measure the phase and frequency errors of the signal during reception, it is conceptually possible

20 to correct for them. The phase error of a received I / Q vector can be estimated based on knowledge of the channel estimate and the transmitted constellation point, by directly measuring the angle from the expected constellation point and the actual received vector. This estimate is perturbed by er-

25 rors in the channel estimate and by noise; an improved estimate for the phase can be obtained in an OFDM symbol by measuring the phase error over a number of subcarriers, possibly also with weighting according to the strength of the subcarrier signals.

The frequency error is simply the change in the phase esti-
mate with time, and can be estimated by dividing the phase
change between two symbols with the symbol period.

As mentioned, in order to estimate the phase and frequency
5   error, it is necessary to know the constellation point corre-
sponding to the transmitted signal. One possible solution to
this problem is to use the demodulated data to try to deter-
mine the correct constellation point, using an architecture
such as that shown in Figure 4, called data-driven phase and
10   frequency tracking. The corresponding function blocks in Fig-
ures 2 and 4 have been denoted with the same reference signs
and will not be explained again. In Figure 4 there is also
disclosed a frequency estimation block 18 connected to the
block 12 and to the block 10. Finally, there is also a remodu-
15   lation block 20 connected to the frequency estimation block
18. Demodulated data can be taken at two possible locations:
for greatest robustness, it should be taken at the output of
the error correction block, since this ensures the minimum
number of selection errors. However, it may also be taken from
20   before the error correction block.

This demodulated data is then re-modulated (mapped back into
I / Q constellation points) for each subcarrier in the OFDM
symbol, based on the channel estimate. It is then possible to
use all of the subcarriers in the OFDM symbol to make an es-
25   timate of the overall phase rotation of the OFDM symbol.

Typically, this phase error is used as an input to a PID
(proportional, integral, derivative) control loop, which uses
the instantaneous estimates for the phase and frequency error
plus an integral phase term to drive the input to the fre-
30   quency correction block, thereby simultaneously tracking er-
rors in both phase and frequency.

As was mentioned earlier, an IEEE 802.11a OFDM transmission
uses only 48 of the 52 subcarriers for carrying data. The re-
maining 4 pilot tones are modulated with a known sequence,
and these can therefore be used directly for the measurement
5   of phase error.

An example architecture is shown in Figure 5, called pilot-
based phase and frequency tracking. The corresponding func-
tion blocks in Figures 2, 4 and 5 have been denoted with the
same reference signs and will not be explained again. In Fig-
10   ure 5 there is also disclosed a phase correction block 22
connected to the block 12 and to the block 14. Finally, there
is also a pilot-based phase estimation block 24 connected to
the block 10 and to the block 22. The pilot-based phase esti-
mation block extracts the pilot subcarriers from the data
15   stream, and uses them to calculate an estimate of the phase
rotation for the current OFDM symbol. This estimate of the
phase error is then used by the phase correction block, which
de-rotates the received symbol prior to demodulation.

It is also necessary to correct the frequency error in order
20   to avoid loss of FFT orthogonality. This is done by estimat-
ing the residual frequency error based on the symbol-by-
symbol rate of phase change, and feeding back this estimate
to the frequency correction block, which adds the residual
frequency error estimate to the correction frequency.

25   Data-driven frequency and phase tracking has the advantage
that it maximises noise rejection by taking into account all
of the available subcarriers in the signal. However, a major
drawback is that, in order to obtain reliable data estimates,
it is necessary to take the data from the output of the error
30   correction block. This block has a large latency (usually
several data symbols), which means that the frequency track-

6

ing loop is very slow to respond. For all but very minor re-
sidual frequency errors, the accumulated phase error will be-
come so great that demodulation fails and the frequency
tracking loop breaks down.

5   The pilot-based method is very robust, since the pilot tones
are known in advance and the phase correction is applied im-
mediately, and can therefore cope with large and rapid swings
in frequency. The problem with the pilot-based solution, how-
ever, is the noise introduced by the phase estimate due to it
10 being made over only the 4 pilot subcarriers. This noise di-
rectly modulates the received symbol, increasing the error
vector magnitude and thereby the error probability.

Since large and rapid frequency deviations are observed only
near the beginning of the transmission, it is desirable to be
15 able to use robust pilot-based tracking near the beginning of
the transmission, but to switch over to less noisy, but
slower data-based tracking for the remainder of the transmis-
sion, using a combined architecture such as that shown in
Figure 6. The corresponding function blocks in Figures 2, 4 -
20 6 have been denoted with the same reference signs and will
not be explained again. However, this is difficult to achieve
in practice, due to the error properties of the pilot-based
tracking method.

The phase estimate calculated from the pilot subcarriers has
25 an accuracy that is adequate for demodulation. However, the
frequency error is based on the slope calculated over two
such noisy estimates, and is therefore much more prone to
noise which causes random frequency deviations from the sym-
bol to symbol.

When the pilot-based phase correction is being performed, the phase deviations from these random frequency deviations are corrected for. However, when pilot-based tracking is deactivated, the frequency correction block maintains the frequency

5   error from the last estimate. Since the data-based frequency tracking loop has·a latency of several symbols, the overall phase error increases in just the same way as happened with the original VCO frequency deviation, and will often cause failure before the frequency tracking loop can correct for

10   the residual error.

SUMMARY OF THE INVENTION

The object with the present invention is to solve the above mentioned problems. The tracking system according to the present invention is comprised in a receiver. The tracking sys-

15   tem is operable to track rapid changes in frequency and phase offset of the received signal. The tracking system comprises a first system operable to perform a pilot-based phase and frequency tracking. The tracking system also comprises a second system operable to perform data-based phase and frequency

20   tracking. The tracking system also comprises control means connected to said first system and to said second system, wherein the control means is operable to gradually reduce the effect of said first system.

25   An advantage of the tracking system according to the present invention is that it allows a smooth transition from pilot-based to data-based frequency estimation. This allows the receiver to deal with violent frequency deviations during the VCO settling at the start of the transmission, while minimis-

30   ing the error vector magnitude and thereby also minimising the packet error probability for long transmissions.

8

A further advantage in this connection is achieved if said control means comprises at least one weighting means operable to gradually decrease the weight factors to gradually reduce said effect of said first system.

5

In this connection, a further advantage is achieved if said control means also comprises a first estimating means operable to perform an estimate of the phase of the received symbol, and a phase differentiator connected to said first esti-

10   mating means wherein the phase differentiator is operable to calculate the phase increment between two consecutive symbols. In addition, a first weighting means is connected to the phase differentiator, and a frequency scaling means is connected to the weighting means, wherein the frequency scal-

15   ing means is operable to scale the weighted value to obtain a frequency correction increment output.

A further advantage in this connection is achieved if said control means also comprises a second weighting means con-

20   nected to said phase differentiator that is operable to multiply said phase increment with a weight factor. In addition, a phase integrator is connected to said second weighting means and is operable to sum together all of said individual phase increments to obtain a phase error estimate out-

25   put.

In this connection, a further advantage is achieved if said control means also comprises a symbol counter means connected to said first weighting means and to said second weighting

30   means that is operable to count the symbols in order to use a weight factor that depends on the symbol number.

A further advantage in this connection is achieved if said
system comprises a frequency correction means operable to
correct a frequency error of a received symbol. In addition,
a transforming means is connected to said frequency correc-

5   tion means and is operable to perform a Fourier transform op-
eration resulting in a number of independently modulated sub-
carriers, wherein said transforming means is connected to
said first estimating means and said frequency scaling means
is connected to said frequency correction means. The track-

10   ing system also comprises a phase correction means operable
to perform a correction of the symbol phase, wherein the
phase correction means also is connected to said phase inte-
grator. In addition, a demodulating means is connected to
said phase correction means and is operable to demodulate

15   said phase-corrected symbol to produce a data stream, and a
remodulating means is connected to said demodulating means
and is operable to remodulate said data stream. Lastly, a
frequency estimation means is connected to said remodulating
means, and an error correction means is connected to said de-

20   modulating means resulting in said final estimate of the re-
ceived data symbols.

In this connection, a further advantage is achieved if said
weight factors are set to 1 up to where the transition from

25   pilot-based phase and frequency tracking to data-based phase
and frequency tracking is to occur.

A further advantage in this connection is achieved if said
weight factors for the same symbol number are equal for said

30   first weighting means and for said second weighting means.

A further advantage in another embodiment is achieved if said
weight factors for the same symbol number are unequal for

10

said first weighting means and for said second weighting means.

The above mentioned problems are also solved with a method
5   for tracking rapid changes in frequency and phase offset in a receiver. The method comprises: performing a pilot-based phase and frequency tracking, and performing a data-based phase and frequency tracking. The method further comprises: gradually reducing the effect of said pilot-based phase and
10   frequency tracking.

An advantage with the method for tracking rapid changes in frequency and phase offset in a receiver according to the present invention is that it allows a smooth transition from
15   pilot-based to data-based frequency estimation. This allows the receiver to deal with violent frequency deviations during the VCO settling at the start of the transmission, which minimises the error vector magnitude and thereby also mini- mises the packet error probability for long transmissions.
20

A further advantage in this connection is achieved if said method also comprises: gradually decreasing weight factors in order to gradually reduce the effect of said pilot-based phase and frequency tracking.
25

In this connection, a further advantage is achieved if said method also comprises: performing an estimate of the phase of the received symbol, calculating the phase increment be- tween two consecutive symbols, weighting said phase increment
30   with a first weight factor, and scaling said weighted value to obtain a frequency correction increment output.

A further advantage in this connection is achieved if said method comprises: weighting said phase increment with a second weight factor, and summing together all of said individual phase increments to obtain a phase error estimate output.

5

In this connection, a further advantage is achieved if said method also comprises: counting the symbols in order to use a weight factor that depends on the symbol number.

10 A further advantage in this connection is achieved if said method also comprises: correcting a frequency error of a received symbol, performing a Fourier transform operation resulting in a number of independently modulated subcarriers, performing a correction of the symbol phase, demodulating

15 said phase-corrected symbol to produce a data stream, remodulating said data stream, and performing an error correction resulting in a final estimate of the received data symbols.

In this connection, a further advantage is achieved if said

20 weight factors are set to 1 up to where the transition from pilot-based phase and frequency tracking to data-based phase and frequency tracking is to occur.

A further advantage in this connection is achieved if said

25 first weight factor and said second weight factor for the same symbol number are equal.

A further advantage in another embodiment is achieved if said first weight factor and said second weight factor for the

30 same symbol number are unequal.

The above mentioned problems are also solved with at least one computer program product. The computer program prod-

uct(s) is/are directly loadable into the internal memory of at least one digital computer, comprising software code portion for performing the method described above when said product(s) is/are run on said at least one computer.

5

An advantage with the computer program product according to the present invention is that it allows a smooth transition from pilot-based to data-based frequency estimation. This allows the receiver to deal with violent frequency deviations

10 during the VCO setting at the start of the transmission, while minimising the error vector magnitude and thereby also minimising the packet error probability for long transmissions.

15 Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustra-

20 tion only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

25   BRIEF DESCRIPTION OF THE DRAWINGS
The present invention will become more fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and thus are not limiting of the present invention and

30 wherein:

Figure 1 shows an example of a VCO frequency deviation profile in relation to a 802. 11 a preamble;

13

Figure 2 is a block diagram of a digital OFDM receiver according to the prior art;

5 Figure 3 is a I-Q-diagram disclosing the effect of signal phase rotation on demodulation;

Figure 4 is a block diagram of a data-based frequency and phase tracking system according to the prior art;

10

Figure 5 is a block diagram of a pilot-based phase and frequency tracking system according to the prior art;

Figure 6 is a block diagram of a combined pilot- and data-

15 based frequency and phase tracking system according to the prior art;

Figure 7 is a block diagram of a tracking system operable to track rapid changes in frequency and phase offset according

20 to the present invention;

Figure 8 is a more detailed block diagram of the tracking system disclosed in Figure 7;

25 Figure 9 is a flow chart of a method for tracking rapid changes in frequency and phase offset in a receiver according to the present invention;

Figures 10(1) and 10(2) is a more detailed flow chart of the

30 method disclosed in Figure 9; and

Figure 11 show some examples of computer program products according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In figure 7 there is disclosed a block diagram of a tracking system 100 according to the present invention. The tracking

5   system 100 is comprised in a receiver 300, which only is disclosed diagrammatically in Figure 7. The tracking system 100 is operable to track rapid changes in frequency and phase offset of the received signal. The tracking system 100 comprises a first system 102 operable to perform a pilot-based

10   phase and frequency tracking. The tracking system 100 also comprises a second system 104 operable to perform data-based phase and frequency tracking. As is apparent from figure 7, the first system 102 is connected to the second system 104. The tracking system 100 also comprises a control means 106

15   connected to said first system 102 and to said second system 104 that is operable to gradually reduce the effect of said first system 102. This means that the transition from pilot-based to data-based phase and frequency tracking can be smooth, by gradually reducing the effect of the pilot-based

20   tracking function rather than immediately switching it off. This allows the data-based tracking loop time to observe and correct for residual frequency error before the total phase error becomes large enough to cause demodulation errors.

25   In figure 8 there is disclosed a more detailed block diagram of the tracking system 100 disclosed in figure 7. The tracking system 100 comprises a frequency correction means 10 operable to correct a frequency error of a received symbol A, e.g. I/Q Rx samples. A transforming means 12 is connected to

30   said frequency correction means 10, which transforming means 12 is operable to perform a Fourier transform operation resulting in a number of independently modulated subcarriers.

The tracking system 100 also comprises a first estimating means 110 operable to perform an estimate of the phase of the received symbol based on the pilot tones. Connected to the first estimating means 110 is a phase differentiator 112 op-

5   erable to calculate the phase increment between two consecutive symbols. The tracking system 100 also comprises a first weighting means 114 connected to the phase differentiator 112 that is operable to multiply the phase increment with a weight factor. Connected to said first weighting means 114 is

10   a frequency scaling means 116 operable to scale the weighted value to obtain a frequency correction increment output which is input to said frequency correction means 10. The tracking system 100 also comprises a second weighting means 120 connected to said phase differentiator 112. The second weight

15   means 120 is operable to multiply the extent of said phase differentiator 112 with a weight factor. Connected to said second weighting means 120 is a phase integrator 122 operable to sum together all of said individual phase increments to obtain a phase error estimate output which is input to a

20   phase correction means 22 operable to perform a correction of the symbol phase. The tracking system 100 also comprises a demodulating means 14 connected to said phase correction means 22 that is operable to demodulate said phase-corrected symbol to produce a data stream. The tracking system 100 also

25   comprises an error correction means 16 connected to said demodulating means 14 resulting in an estimate of the error-corrected data stream. The tracking system 100 also comprises a remodulating means 20 connected to said error correction means 16 that is operable to remodulate said data stream.

30   Connected to said remodulating means 20 is a frequency estimating means 18, which uses the instantaneous estimates for the phase and frequency error plus an integral phase term to drive the input to the frequency correction means 10. The

tracking system 100 also comprises a symbol counter means 118 connected to said first weighting means 114 and to said second weighting means 120 that is operable to count the symbols in order to use a weight factor that depends on the symbol

5   number.

In a preferred embodiment of said tracking system said weight factors are set to 1 up to where the transition from pilot-based phase and frequency tracking to data-based phase and

10   frequency tracking is to occur,

In one embodiment of the tracking system 100 said weight factors for the same symbol number are equal for said first weighting means 114 and for said second weighting means 120.

15

In another embodiment of the tracking system 100 said weight factors for the same symbol number are unequal for said first weight weighting means 114 and for said second weighting means 120. This means that the transition points for the fre-

20   quency and phase correction does not occur at the same place. For instance, it is advantageous to begin to reduce the frequency error correction a little earlier than the phase correction is reduced, so that the magnitude of the frequency deviations is reduced.

25

The same can be expressed with other words.

The weight factors are set to 1 up to the point where the transition from phase-to-data-based tracking is to occur. The

30   pilot-based tracking is therefore completely functional up to this point; the data-based tracking may also be active at this stage, but will have a little effect since the phase er-

ror is being effectively removed (except for a small remain-
ing random error).

At the point where the transition is to occur, after the ini-
5   tial VCO transient has subsided, the weight factors are
gradually decreased. This means that the magnitude of the
frequency correction changes will be gradually reduced. The
phase correction will begin to change by less than the change
in the phase estimate leading to a small residual error that
10   will pass through to the data-based frequency correction.

In a digital implementation, the weighting factors will typi-
cally be chosen to be simple binary numbers, e.g. a weighting
sequence might be 1,1…1,0.75, 0.75, 0.75, 0.5, 0.5, 0.25,
15   0.25, 0.25, 0, 0…

In figure 9 there is disclosed a flow chart of the method for
tracking rapid changes in frequency and phase offset in a re-
ceiver according to the present invention. The method begins
20   at block 210. The method continues, at block 212, with the
step: to perform a pilot-based phase and frequency tracking.
Thereafter, the method continues, at block 214, with the
step: to perform a data-based phase and frequency tracking.
The method continues, at block 216, with the step: to gradu-
25   ally reduce the effect of said pilot-based phase and fre-
quency tracking. The method is finished at block 218. This
means that the transaction from pilot-based to data-based
phase and frequency tracking becomes smooth by gradually re-
ducing the effect of the pilot-based tracking rather than im-
30   mediately switching it off. This allows the data-based track-
ing loop time to observe and correct for residual frequency
errors before the total phase error becomes large enough to
cause demodulation error.

In figures 10(1) and 10(2) there is disclosed a more detailed flow chart of the method disclosed in figure 9. The method begins at block 310. The method continues, at block 312, with

5 the step: to correct a frequency error of a received symbol. Thereafter, the method continues, at block 314, with the step: to perform a Fourier transform operation resulting in a number of independently modulated subcarriers. The method continues, at block 316, with the step: to perform an esti-

10 mate of the phase of the received symbol. Thereafter, the method continues, at block 318, with the step: to calculate the phase increment between two consecutive symbols. The method continues, at block 318, with the step: to count the symbol number, i, wherein $1 \leq i \leq n$, wherein n is an integer.

15 Thereafter, the method continues, at block 320, with the step: to weight said phase increment with a first weight factor number i. The method continues, at block 322, with the step: to scale the weighted value number i, to obtain a frequency correction increment output.

20

Thereafter the method continues, by performing the step according to block 312 of the next symbol. This path of the method only concerns the frequency correction. The phase correction part of the method will be dealt with hereinbelow.

25 The method continues, at block 324, with the step: to weight said phase increment with a second weight factor number i. Thereafter, the method continues, at block 326, with the step: to sum all of said individual phase increments to obtain a phase error estimate output which is input to a func-

30 tion according to block 328. The method then continues, at block 328 of figure 10(2), with the step: to perform a correction of the symbol phase. Thereafter, the method continues, at block 330, with the step: to demodulate said phase-

corrected symbol to produce a data stream. The method contin-
ues, at block 332, with the step: to remodulate said data
stream (map it back into I/Q constellation points). Thereaf-
ter, the method continues, at block 334, with the step: to

5   perform error correction resulting in a final estimate of the
received data symbols. The method continues, at block 336,
with the step: to perform a frequency estimation. Thereafter,
the method continues, to repeat the step according to block
312 of figure 10(1) again. The method is finished at block

10   338.

According to a preferred embodiment of said method, said
weight factors are set to 1 up to where the transition from
pilot-based phase and frequency tracking to data-based phase

15   and frequency tracking is therefore completely functional up
to this point; the frequency-based tracking may also be ac-
tive at this stage, but will have little effect since the
phase error is being effectively removed (except for a small
remaining random error).

20
According to one embodiment of said method, the first weight
factor and the second weight factor for the same symbol, num-
ber, i, are equal.

25   In a digital implementation, the weighting factors will typi-
cally be chosen to be simple binary numbers, e.g. a weighting
sequence might be 1, 1,…1, 0.75, 0.75, +.75, 0.5, 0.5, 0.5,
0.25, 0.25, 0.25, 0, 0,…

30   The transition points for the frequency and phase correction
do not need to occur at the same place. For instance, it is
advantageous to begin to reduce the frequency error correc-

tion a little earlier than the phase correction is reduced, so that the magnitude of the frequency deviations is reduced.

In another embodiment of said method, are said first weight
5 factor and said second weight factor for the same symbol number, i, unequal.

In figure 11 there is disclosed a schematic diagram of some computer program products according to the present invention.
10 There is disclosed n different digital computers 200_1, …, 200_n, wherein n is an integer. There is also disclosed n different computer program products 202_1, …, 202_n, here showed in the form of compact discs. The different computer program products 202_1, …, 202_n are directly loadable into the inter-
15 nal memory of the n different digital computers 200_1, …, 200_n. Each computer program product 202_1, …, 202_n comprises software code portions for performing some or all the steps of figure 9 when the product(s) 202_1 …, 202_n is/are run on said computer(s) 200_1 …, 200_n. Said computer program products
20 202_1, …, 202_n can e. g. be in the form of floppy disks, RAM disks, magnetic tapes, opto magnetical disks or any other suitable products.

The invention is not limited to the embodiments described in the foregoing. It will be obvious that many different modifi-
25 cations are possible within the scope of the following claims.